ELECTRONICS FOR LOW TEMPERATURE SPACE EXPLORATION MISSIONS

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Exploration missions to outer planets and deep space require spacecraft, probes, and on-board data and communication systems to operate reliably and efficiently under severe harsh conditions. On-board electronics, in particular those in direct exposures to the space environment without any shielding or protection, will encounter extreme low temperature and thermal cycling in their service cycle in most of NASA's upcoming exploration missions. For example, Venus atmosphere, Jupiter atmosphere, Moon surface, Pluto orbiter, Mars, comets, Titan, Europa, and James Webb Space Telescope all involve low-temperature surroundings. Therefore, electronics for space exploration missions need to be designed for operation under such environmental conditions.

There are ongoing efforts at the NASA Glenn Research Center (GRC) to establish a database on the operation and reliability of electronic devices and circuits under extreme temperature operation for space applications. This work is being performed under the Extreme Temperature Electronics Program with collaboration and support of the NASA Electronic Parts and Packaging (NEPP) Program. The results of these investigations will be used to establish safe operating areas and to identify degradation and failure modes, and the information will be disseminated to mission planners and system designers for use as tools for proper part selection and in risk mitigation. An overview of this program along with experimental data will be presented.

Abstract for the International Microelectronics and Packaging Society (IMAPS), 2nd Advanced Technology Workshop on *Reliability of Advanced Electronic Packages and Devices in Extreme Cold Environments*, Arcadia, CA, February 27 - March 1, 2007.

Electronics for Low Temperature Space Exploration Missions

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Temperature Data for Planetary Missions

Distance from Sun	Spacecraft Temperature (Sphere, Abs. = 1, Emiss. = 1 Internal Power = 0)	
Mercury	448 K	175 °C
Venus	328 K	55 °C
Earth	279 K	6 °C
Mars	226 K	-47 °C
Jupiter	122 K	-151 °C
Saturn	90 K	-183 °C
Uranus	64 K	-209 °C
Neptune	51 K	-222 °C
(Pluto)	44 K	-229 °C

Planet Temperature Data

Mercury	Slow Rotation Minimum Temp	-180 ºC
Mars	Windy & Dusty	-140 ºC to +20 ºC
Jupiter	Cloudtops	-140 ºC
Europa	Icy Surface	-188 ºC to -143 ºC
Saturn	Cloudtops Mean Temp	-185 ºC
Titan	Surface Temp	-180 ºC
Uranus	Cloudtops	-212 ºC
Neptune	Mean Temp	-225 ºC
Pluto	Mean Temp	-236 ºC

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Earth's Moon

Mean surface temperature (day)	+107 ℃
Mean surface temperature (night)	-153 ℃
Maximum surface temperature	+123 ℃
Minimum surface temperature	-233 ℃

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NEPP Supported Task #07-0281

Requirements and Benefits of Low Temperature Electronics

Requirements

- Electronics Capable of Low Temperature Operation
- High Reliability and Long Life Time
- Improved Energy Density and System Efficiency

Benefits of Low Temperature Electronics

- Survive Deep Space Hostile Cold Environments
- Eliminate Radioisotope and Conventional Heating Units
- Improve System Reliability by Simplified Thermal Management
- Reduce Overall Spacecraft Mass Resulting in Lower Launch Costs

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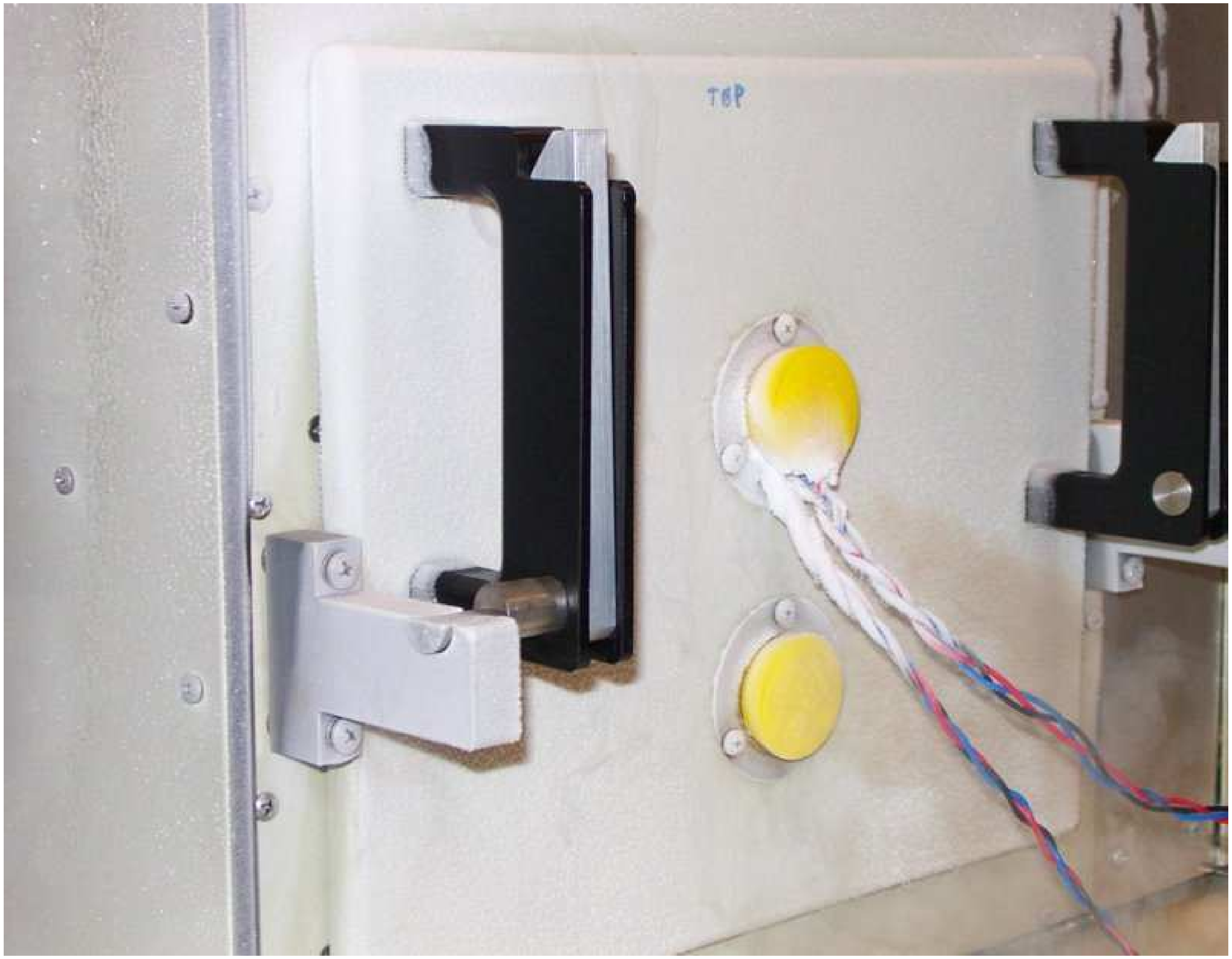

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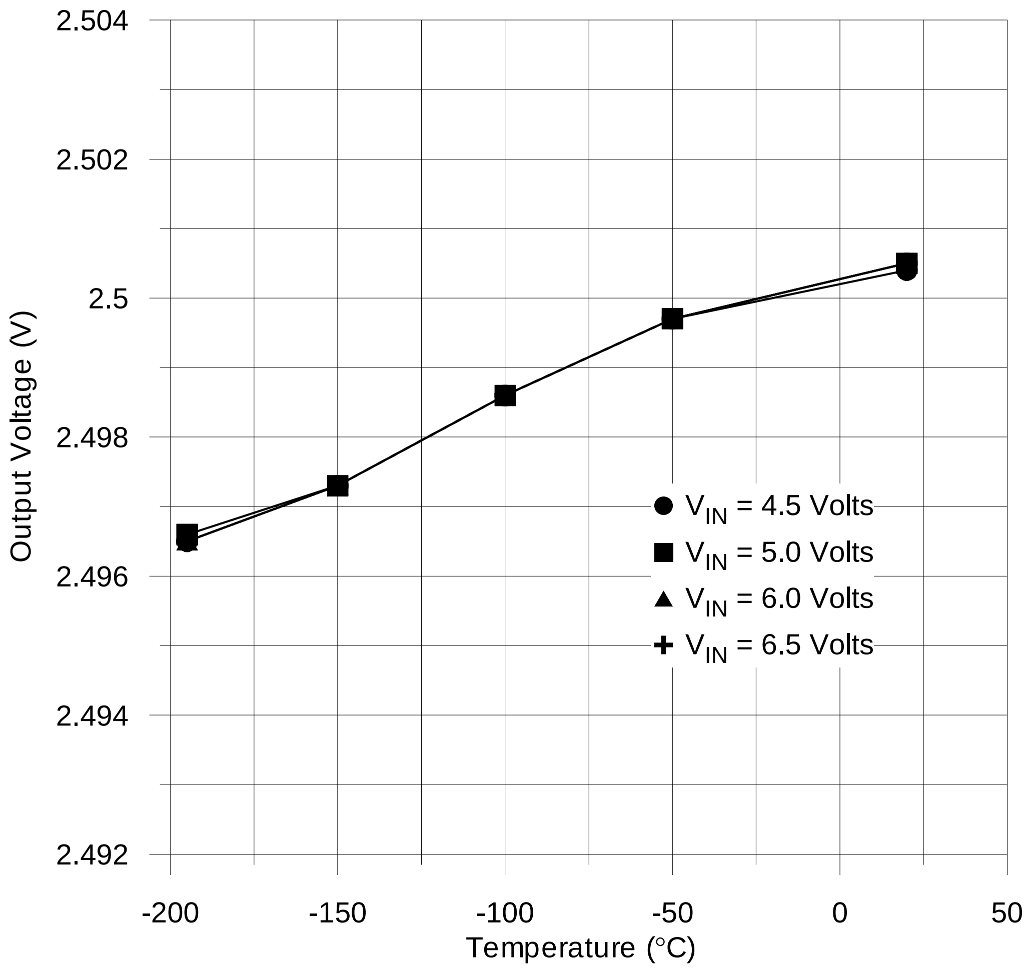
Intersil X60008 Floating Gate Voltage Reference



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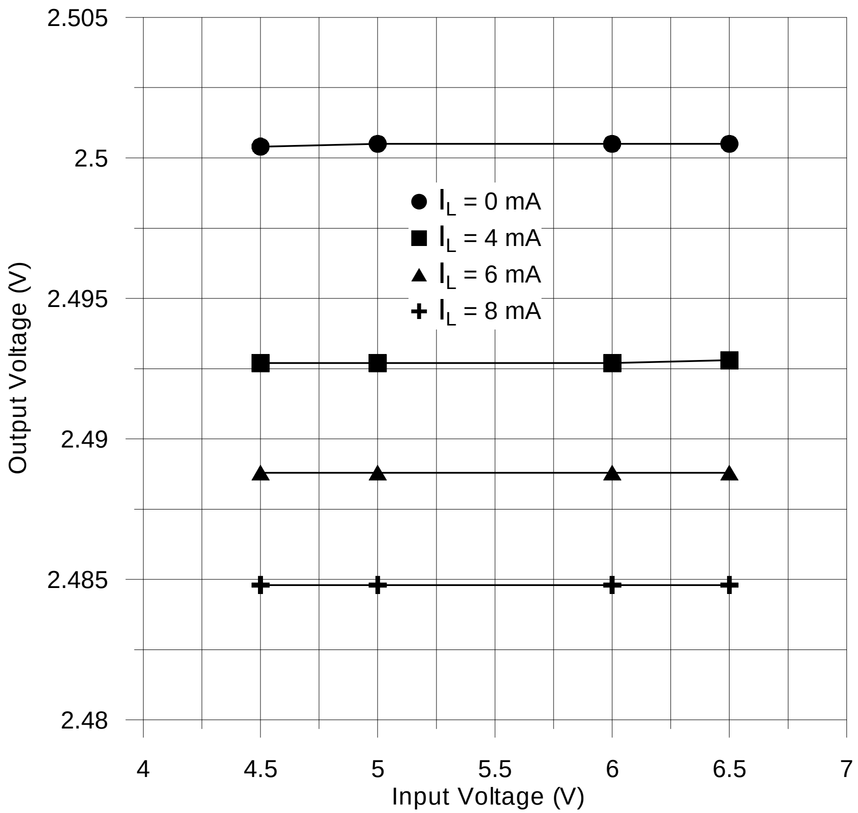
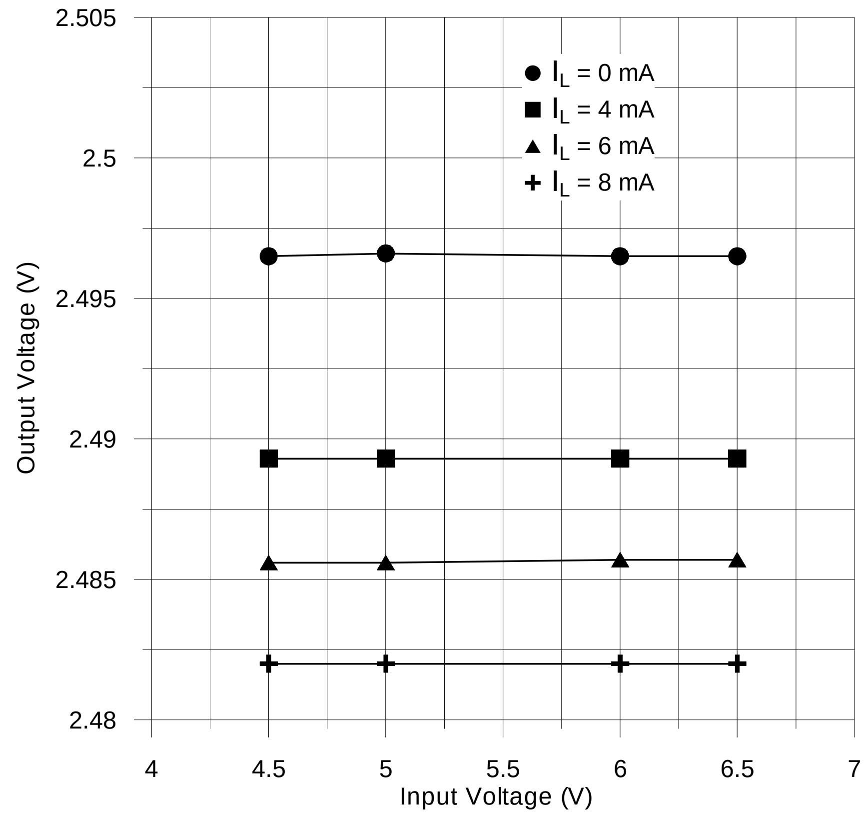
Line Regulation of Intersil X60008 Floating Gate Voltage Reference



20 °C



-195 °C

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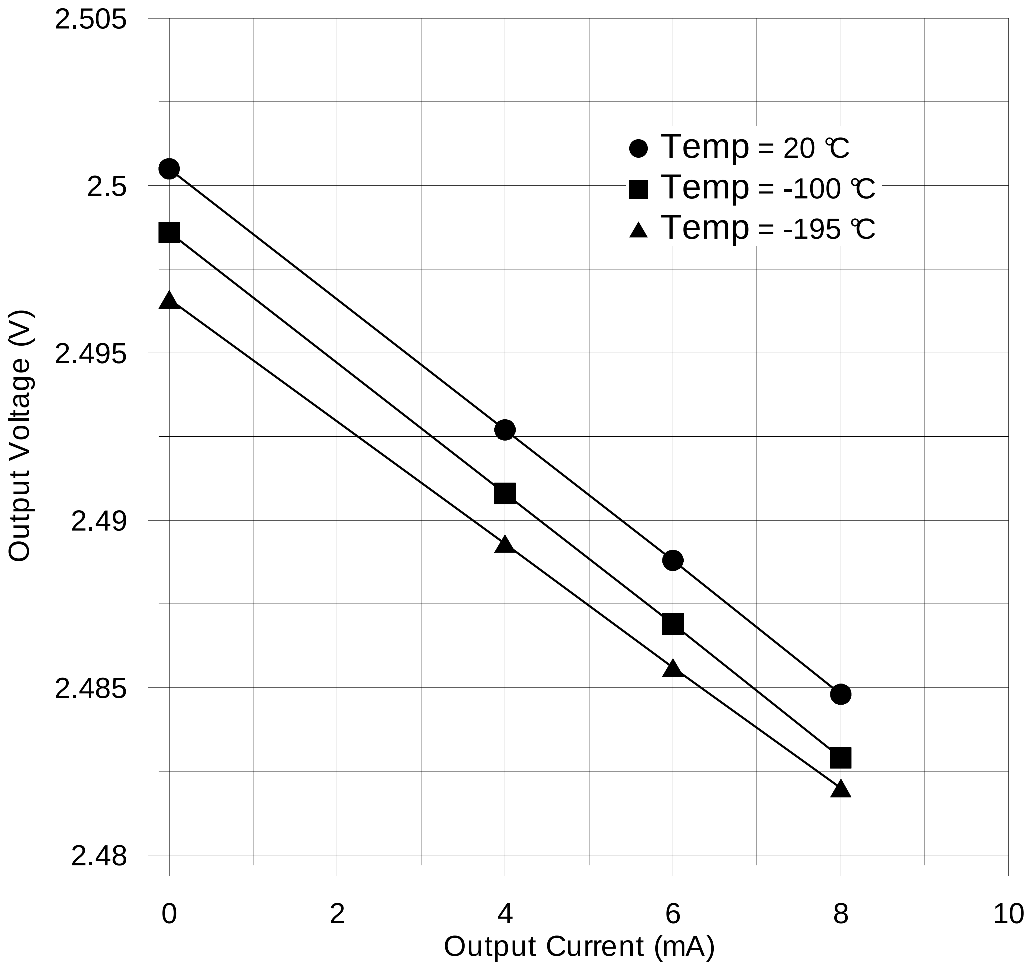
Load Regulation of Intersil X60008 Floating Gate Voltage Reference



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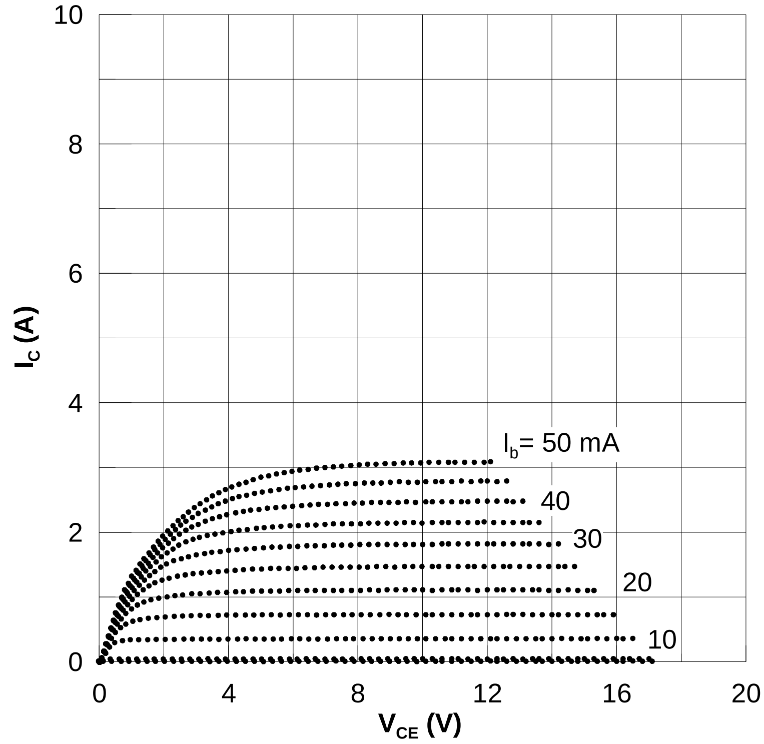
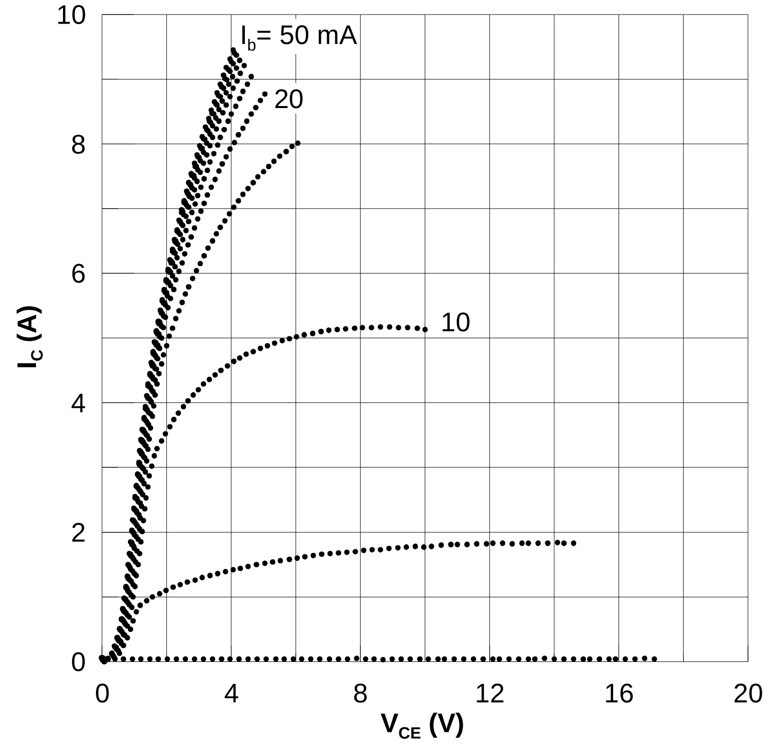
SiGe Hetero-junction Bipolar Power Transistor, HBT (GPD HBT-16-25)



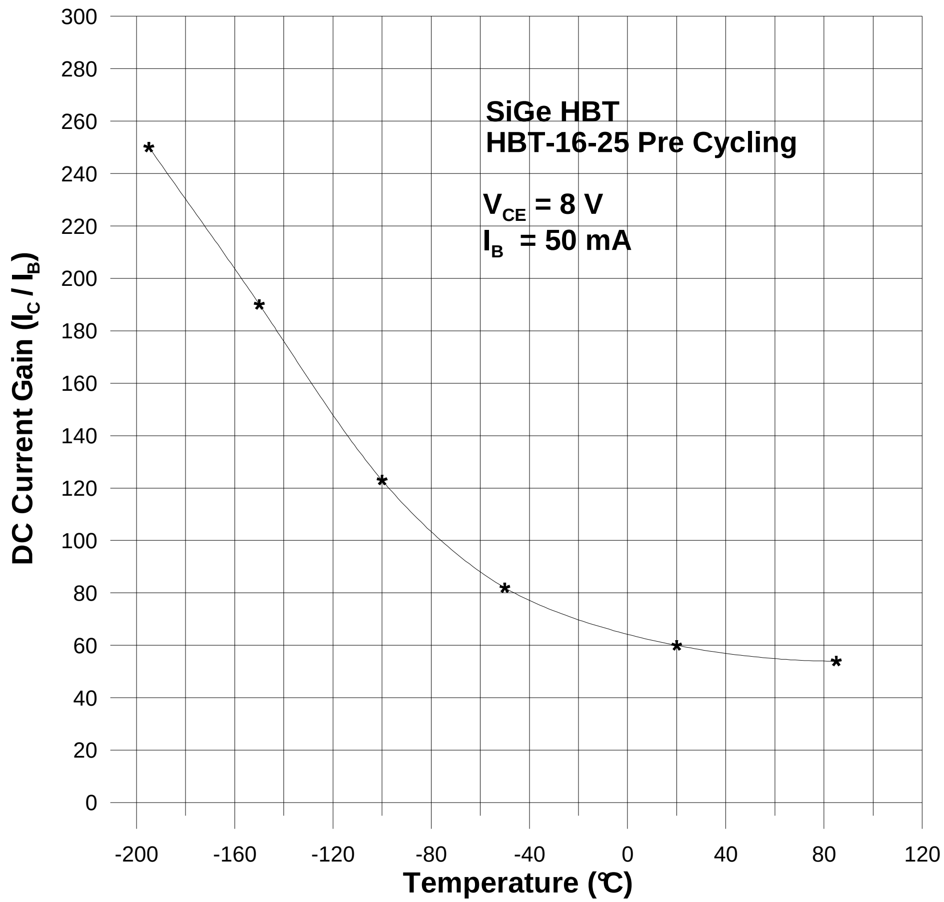
25 °C



-195 °C

NASA GRC Extreme Temperature Electronics

SiGe Hetero-junction Bipolar Power Transistor, HBT (GPD HBT-16-25)



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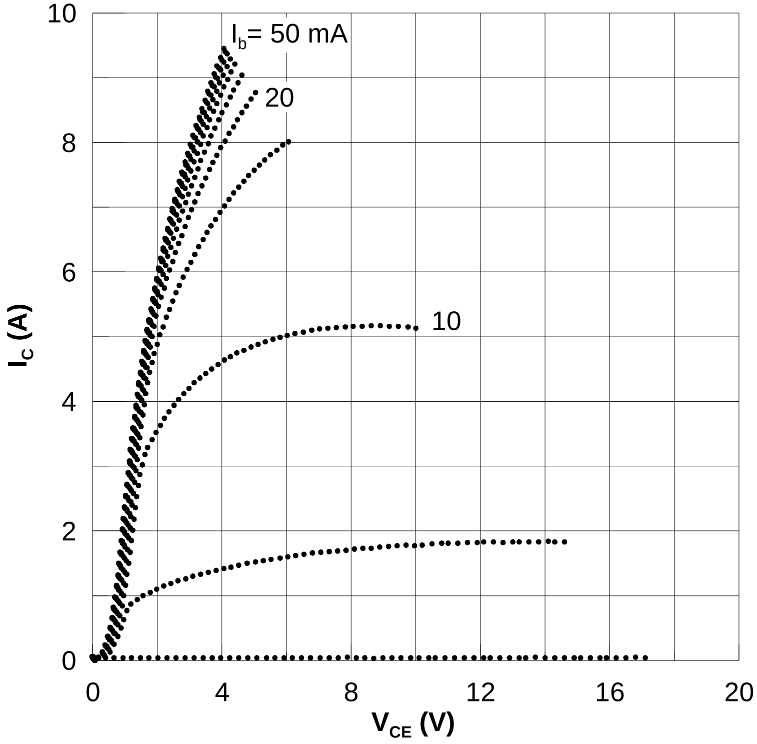
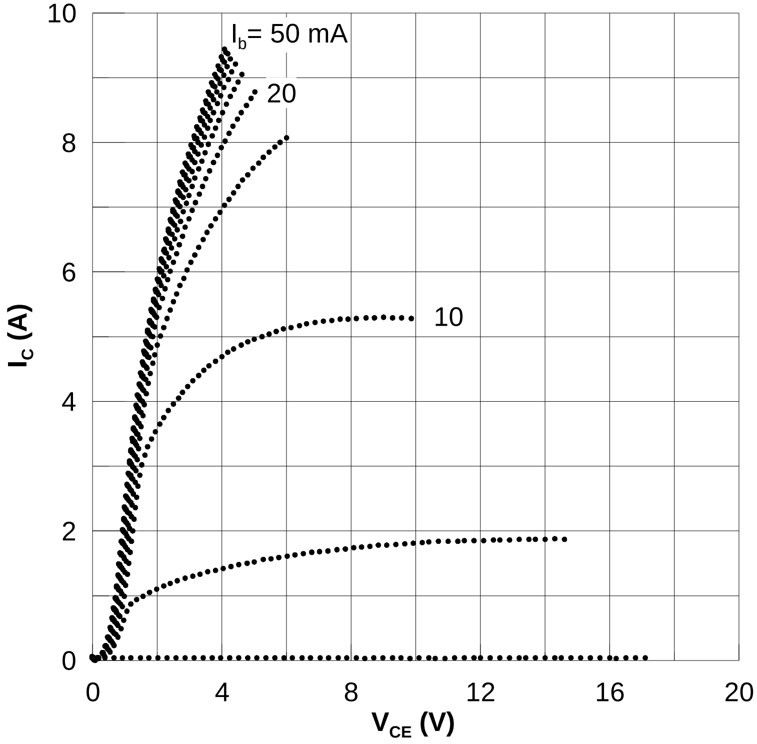
Effects of thermal cycling (12 Cycles; -195 °C to +85 °C) SiGe Hetero-junction Bipolar Power Transistor, HBT (GPD HBT-16-25)



Pre-cycling at -195 °C



Post-cycling at -195 °C

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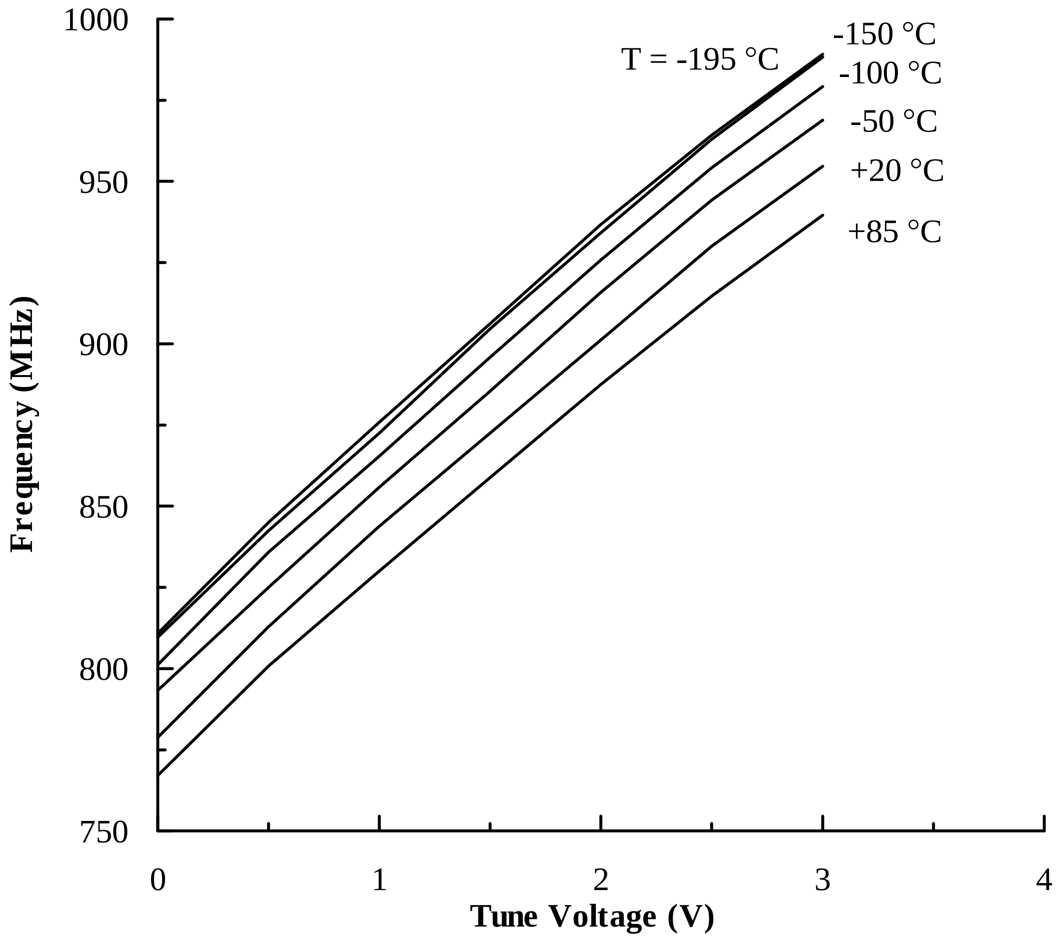
Oscillator Frequency vs Tuning Voltage of a SiGe Voltage-Controlled Oscillator (MAXIM 2622 VCO)



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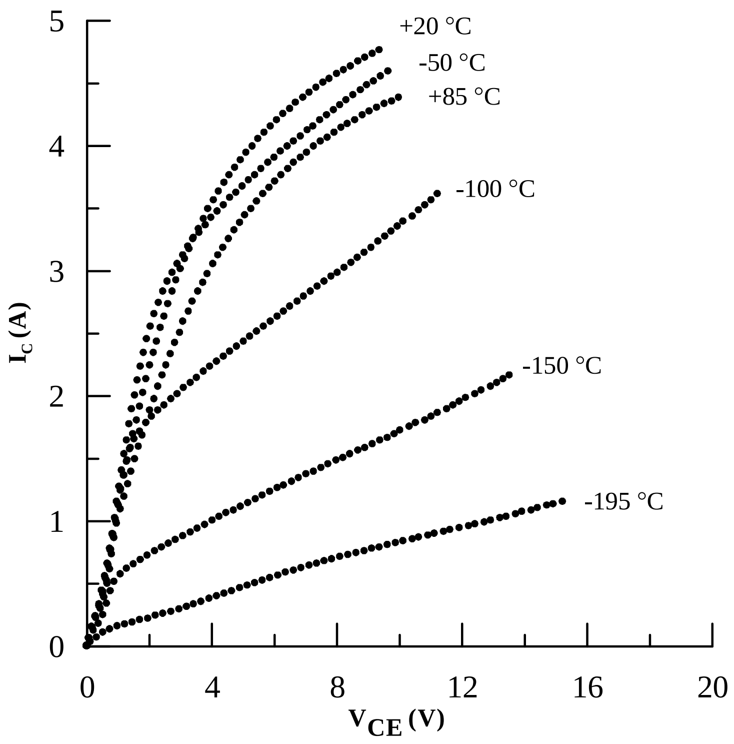
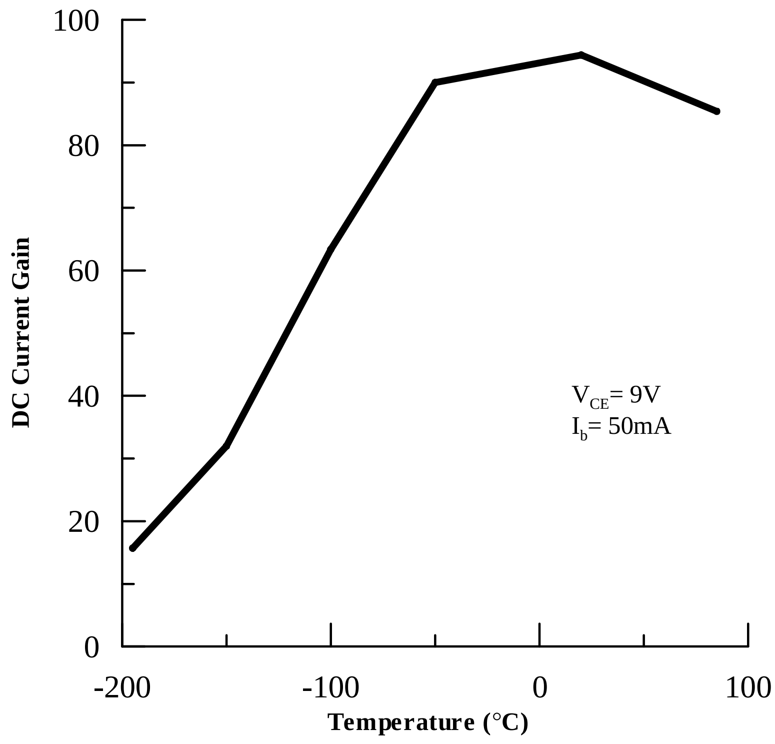
SiGe Hetero-junction Bipolar Power Transistor, HBT (Northrop Grumman ET12F0001AM)





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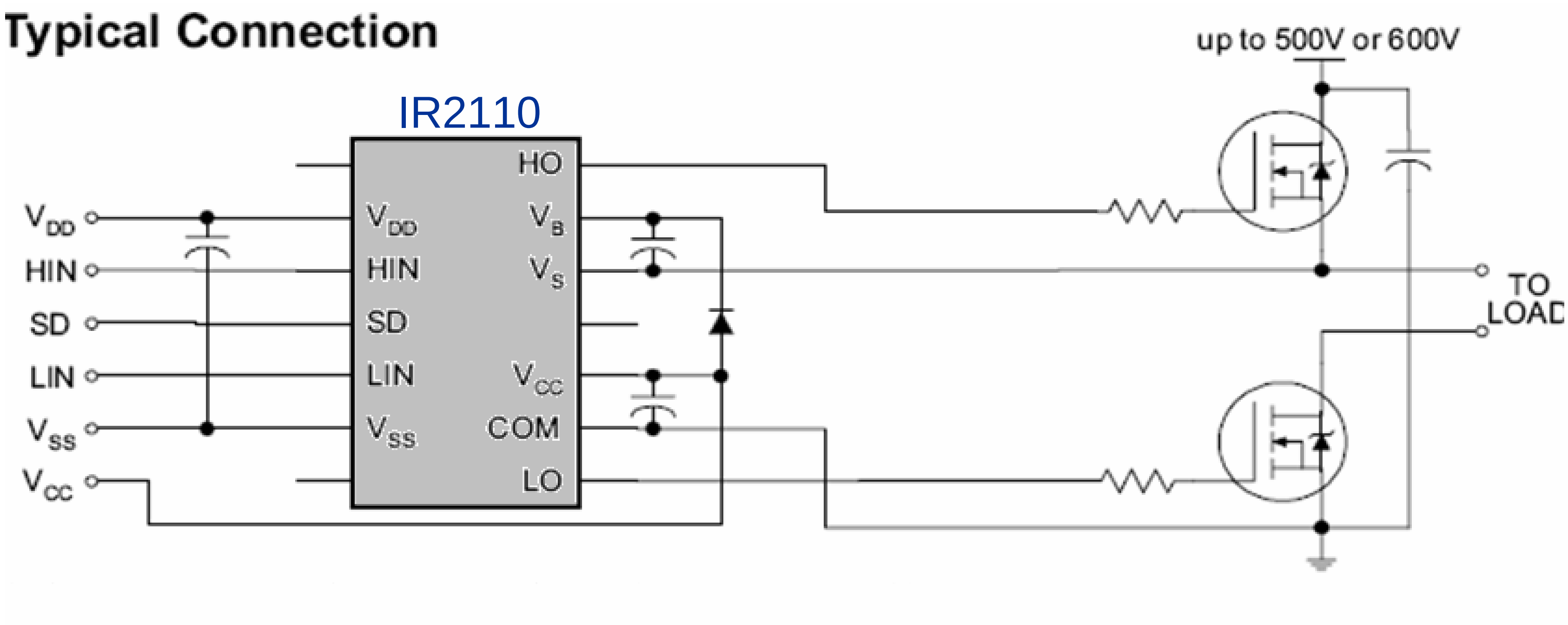
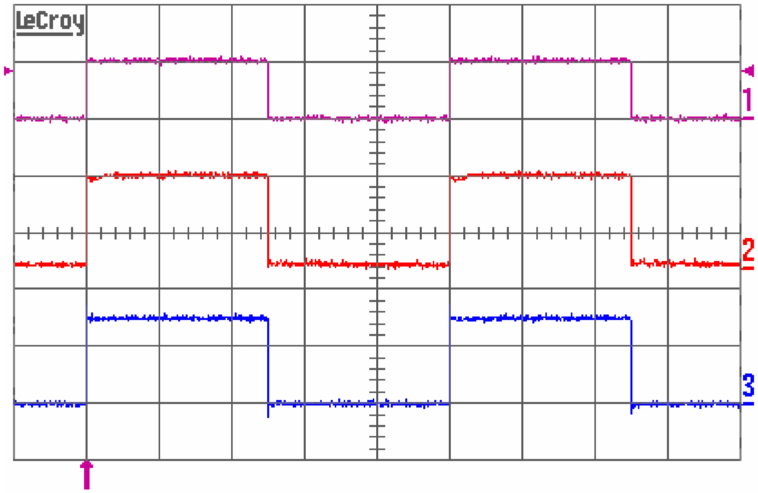
High Voltage Transistor Driver
International Rectifier IR2110



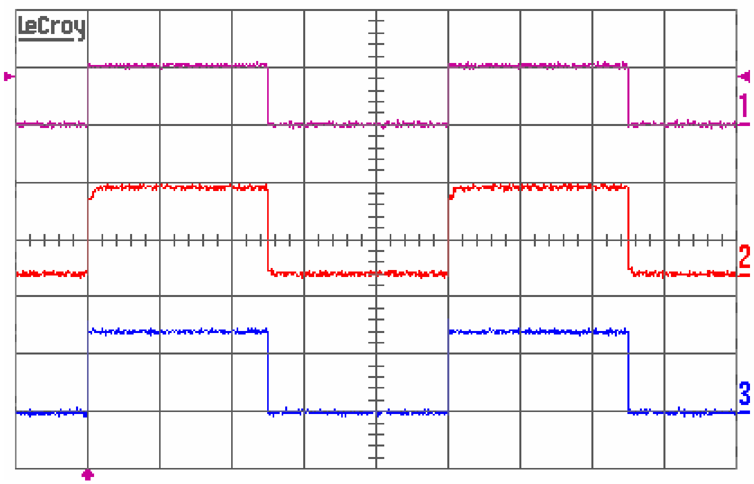
NASA GRC Extreme Temperature Electronics



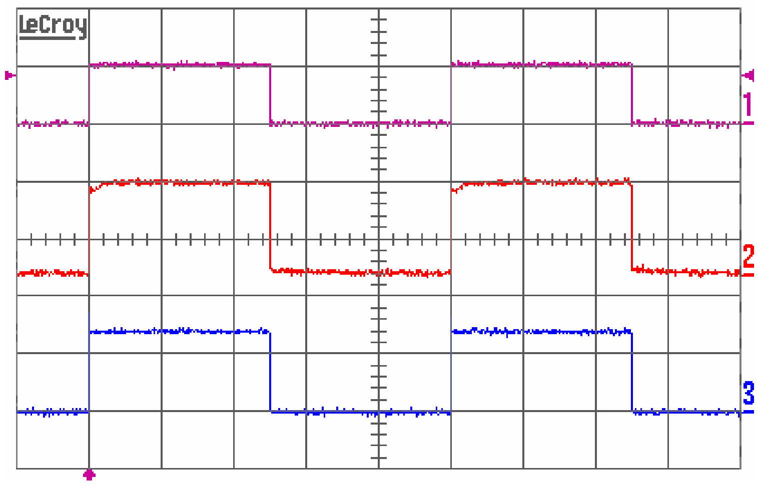
+20 ℃

High Voltage Transistor Driver
International Rectifier IR2110

Waveforms of logic input HIN(#1), output HO(#2) to high side of load, and output LO(#3) to low side of load at various test temperatures



-195 ℃



+100 ℃

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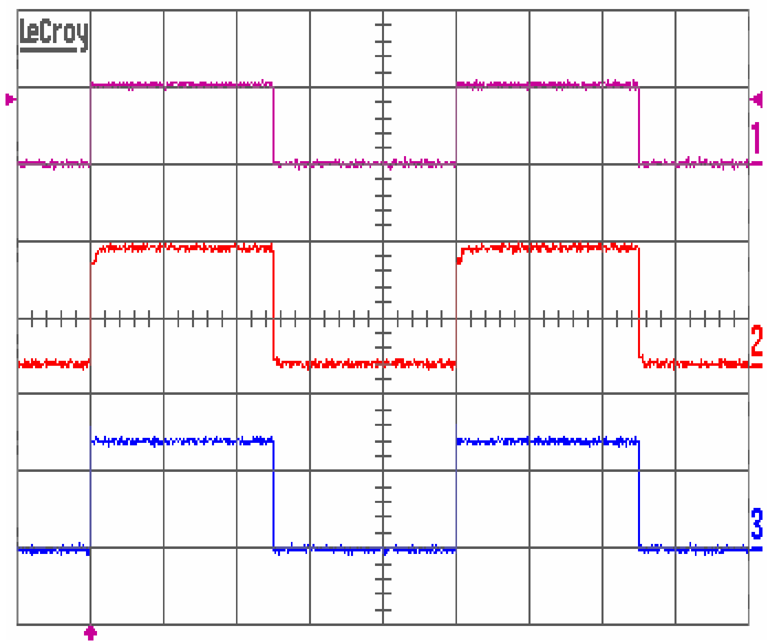
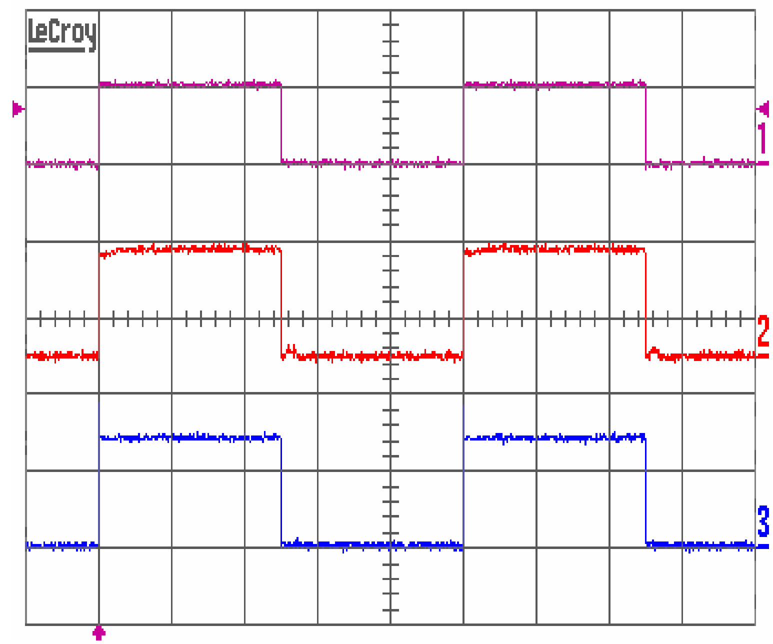
International Rectifier IR2110 High Voltage Transistor Driver

Waveforms of logic input HIN(#1), output HO(#2) to high side of load, and output LO(#3) to low side of load at -195 ℃ be fore and after exposure to ten thermal cycles between -195 ℃ and +100 ℃



-195 ℃ before thermal cycling



-195 ℃ after thermal cycling

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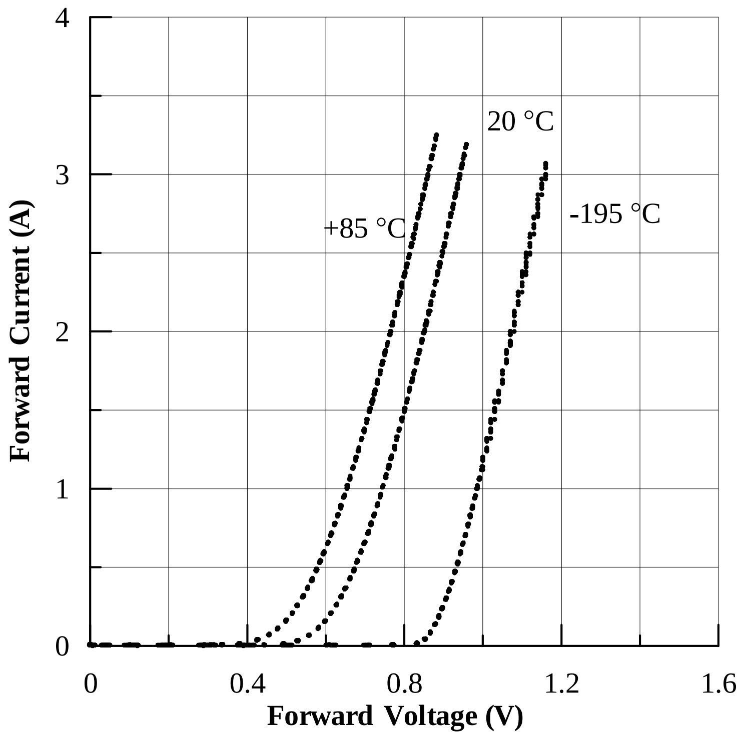
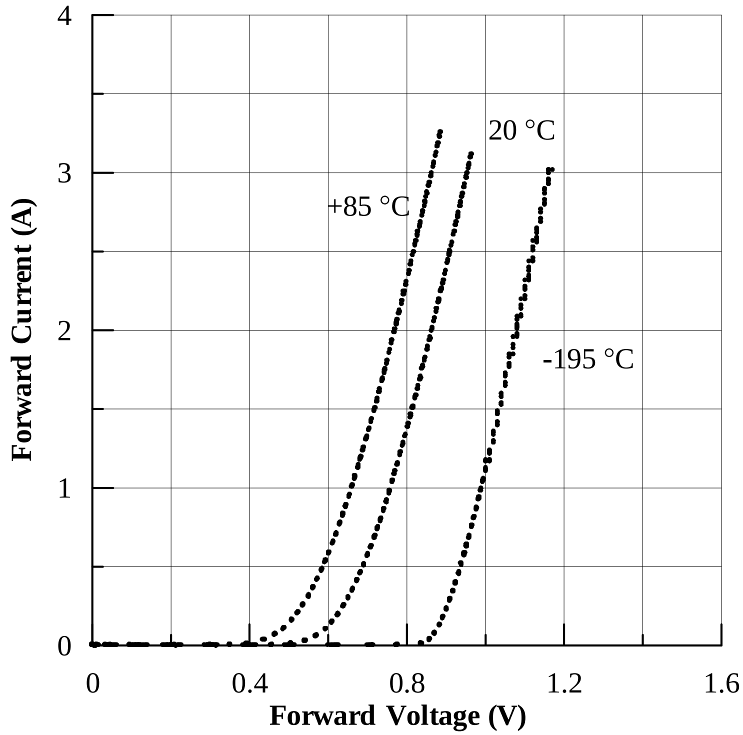
SiGe Power Diode (GPD SG-21-41)

Effects of thermal cycling (12 Cycles; -195 °C to +85 °C)



Pre-cycling



Post-cycling

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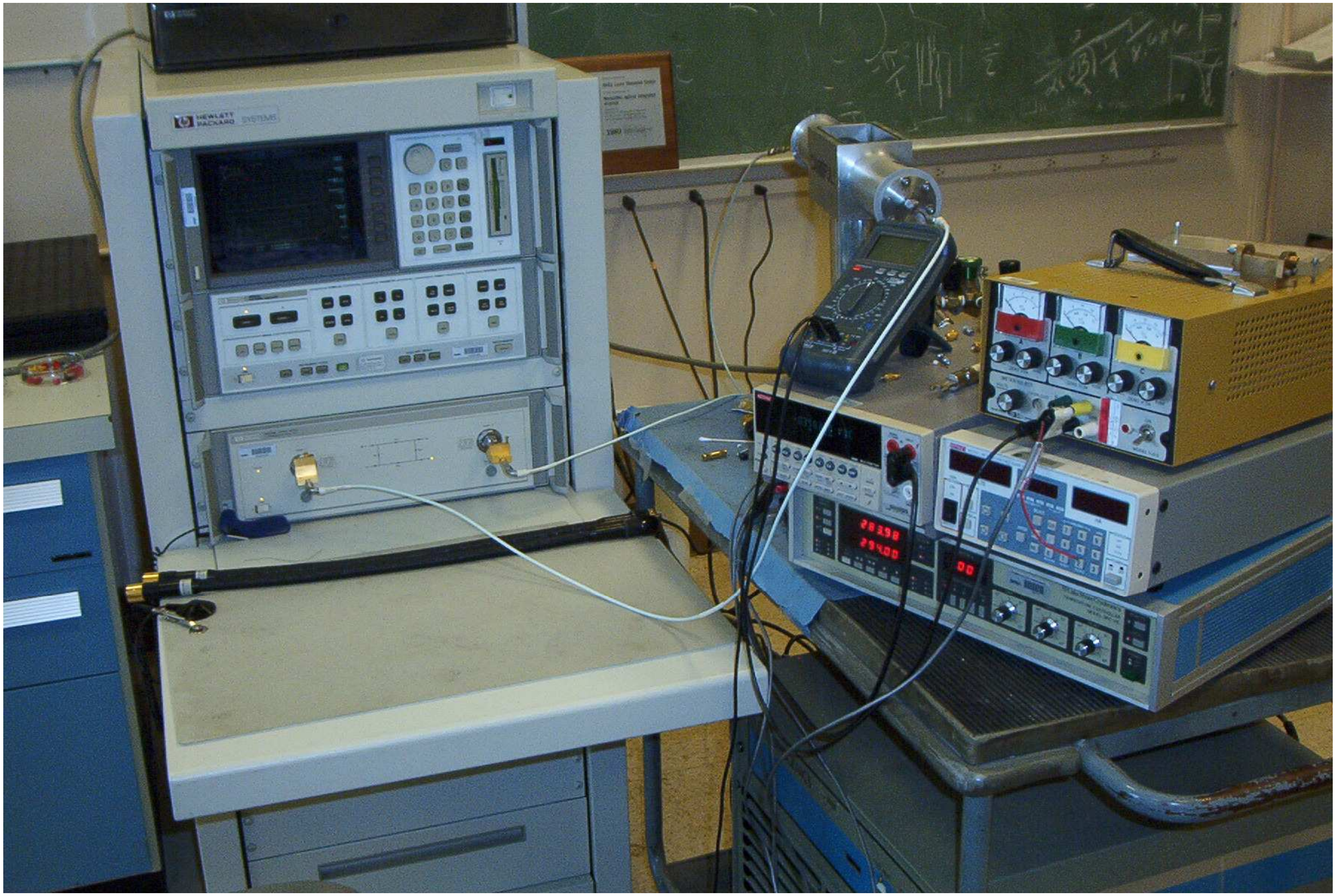
Test Setup for SiGe RF Amplifier Testing



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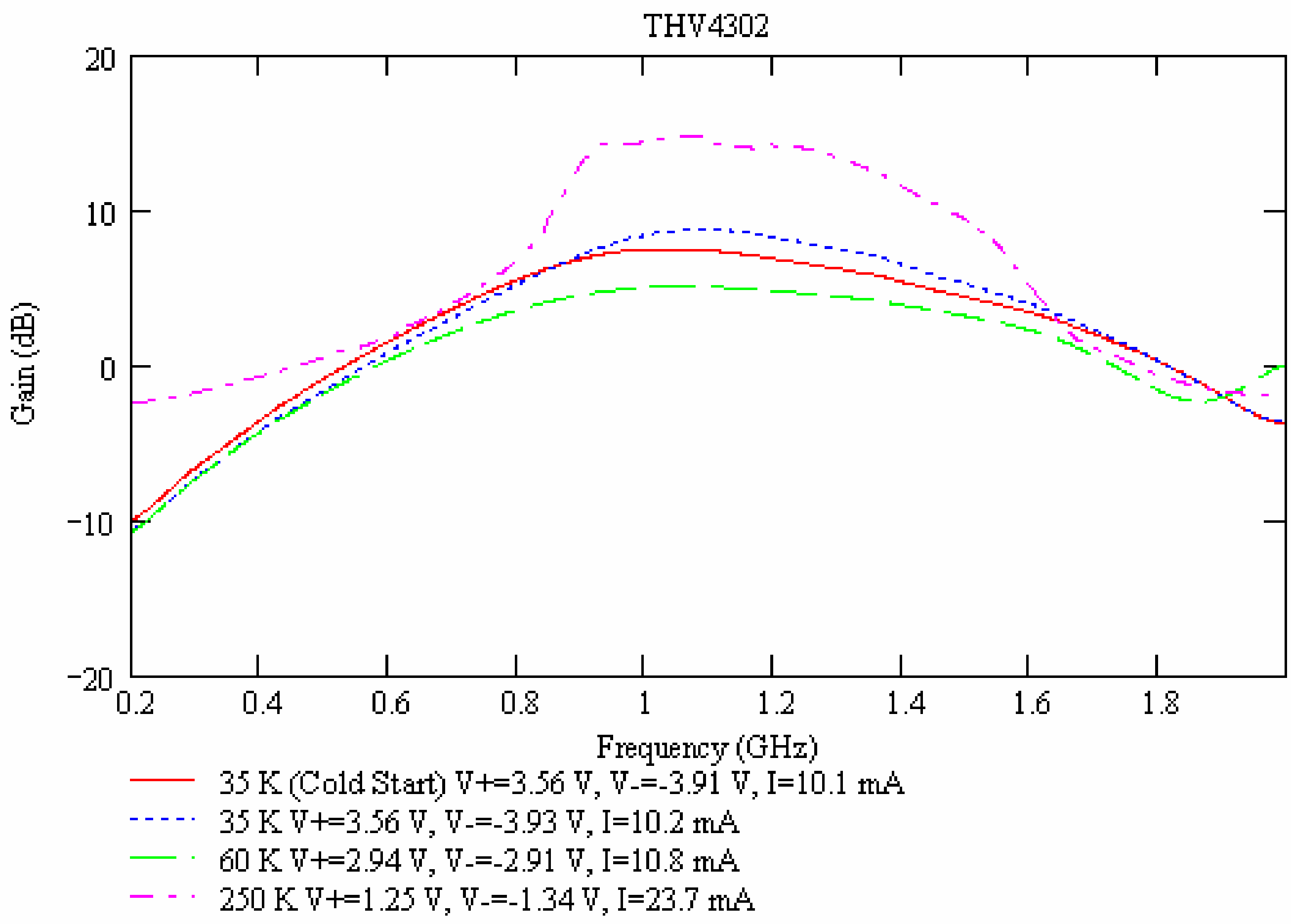
SiGe Radio Frequency Amplifier (Texas Instruments THS4302)



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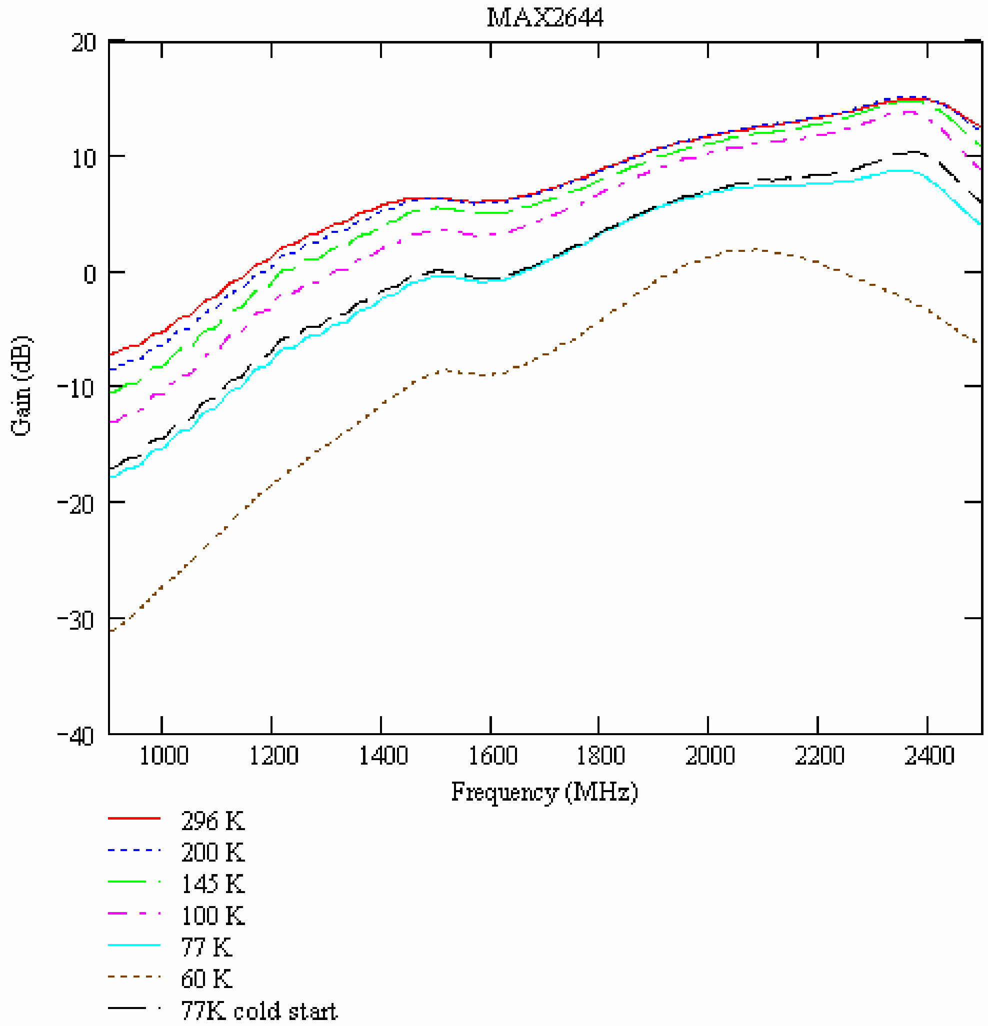
SiGe Radio Frequency Amplifier (Maxim 2644)



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Results for Two SiGe Radio Frequency Amplifiers

Texas Instruments THS4302

- Device functioned with temperature down to 35 K
- Bias was adjusted to maximize gain at midband
- Successful cold-restart at 35 K after 7 min. power off

MAXIM 2644 Evaluation Kit

- Device functioned with temperature down to 60 K
- Gain dropped off significantly below 60 K (Bias may need to be adjusted)
- Successful cold-restart at 60 K after 7 min. power off

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